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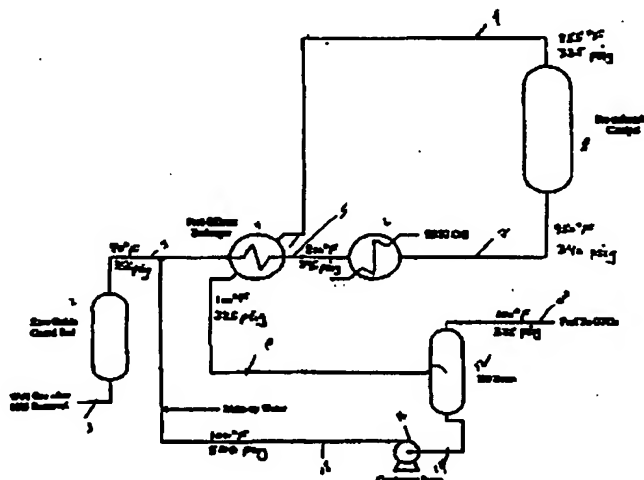
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(54) Title: METHOD FOR UTILIZING GAS RESERVES WITH LOW METHANE CONCENTRATIONS FOR FUELING GAS TURBINES



(57) Abstract: The invention is directed to a method of fueling gas turbines from natural gas reserves with relatively low methane concentrations. The invention permits the use of such reserves to be used to fuel gas turbines to generate electric power. The method of the invention includes providing a natural gas comprising not more than about 40 percent methane on a volume basis and mixing the methane of the natural gas with hydrogen gas to provide a hydrogen enhanced methane/hydrogen gas blend which has sufficient hydrogen to provide flame stability during burning. Thereafter, if required, the hydrogen enhanced methane/hydrogen gas blend is dehydrated to remove a sufficient amount of water to provide a flame stable hydrogen enhanced dehydrated methane/hydrogen gas blend. The hydrogen enhanced natural gas blend is used to fuel gas turbine generators.

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METHOD FOR UTILIZING GAS RESERVES WITH LOW METHANE CONCENTRATIONS FOR FUELING GAS TURBINES

This invention relates to the combustion of natural gas having low
5 methane concentrations and, without the invention, having a low heating value for
the economic generation of power from gas turbines. More particularly, this
invention relates to the combustion of a gas blend with a methane gas
concentration of not more than about 40 volume percent, based upon the total
volume of the gas. The gas blend includes hydrogen gas to increase the
10 combustibility of the gas blend

BACKGROUND OF THE INVENTION

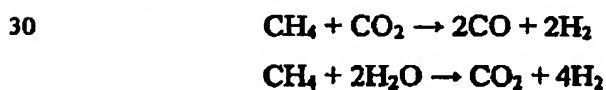
Currently there are substantial methane gas reserves with relatively low
methane gas concentrations. Many of these reserves have methane gas
15 concentrations below 40 volume percent. Currently, impurities are removed from
natural gas to make pipeline quality natural gas which normally have methane
concentrations of from about 95+ to about 99+ volume percent. To fuel gas
turbines to make electric power, converting natural gas having methane
concentrations of not more than about 40 volume percent methane to pipeline
20 quality natural gas becomes economically impractical because the conversion is
capital intensive. Moreover, natural gas with methane concentrations of not more
than 40 volume percent does not provide a reliable fuel source for gas turbines to
generate power because natural gas with such low methane concentrations will not
provide a stable flame for fuel combustion without special catalysts and without
25 special balancing of oxygen with other combustibles.

SUMMARY OF THE INVENTION

The invention is directed to a method of fueling gas turbines from natural
gas reserves with relatively low methane concentrations. The invention permits
30 the use of such reserves to be used to fuel gas turbines to generate electric power.
As described, these reserves currently can be used only after the removal of
impurities to produce suitable gas turbine fuel. Also as previously described, the
latter current technology is capital intensive, and at current natural gas prices,

economically unattractive. The process of the invention can remove the impurities necessary for protection of the environment, leaves inert gasses, such as carbon dioxide, in the fuel to maximize mass flow through the gas turbine, and uses hydrogen gas or shifts just enough methane to hydrogen gas to produce a gas fuel blend of hydrogen and methane gas that not only is an acceptable fuel for gas turbines, but the blend is effective for providing flame stability (such as providing the gas with at least 110 BTUs per standard cubic foot of gas) and for producing more power than a standard natural gas having from about 95+ to about 99+ volume percent methane. The method of the invention includes providing a natural gas comprising not more than about 40 percent methane on a volume basis and mixing the methane of the natural gas with hydrogen gas to provide a hydrogen enhanced methane/hydrogen gas blend (which also may be called a hydrogen enhanced natural gas) which has sufficient hydrogen to provide flame stability during burning. Thereafter, if required, the hydrogen enhanced methane/hydrogen gas blend is dehydrated to remove a sufficient amount of water to provide a flame stable hydrogen enhanced dehydrated methane/hydrogen gas blend. In an important aspect, the hydrogen enhanced methane/hydrogen gas blend has at least about 6 volume percent hydrogen. The flame stable hydrogen enhanced dehydrated methane/hydrogen gas blend then is used to fuel an electric power producing gas turbine. The method of the invention is effective for increasing the power output of a gas turbine by at least about 10 percent as compared to gas turbine using a standard natural gas which comprises from about 95 to about 99+ volume percent methane. In most cases, output may be increased by at least about 20 and up to about 30 percent with these latter limits being imposed by the mechanical design limitations of the gas turbine.

In an important aspect, a portion of the methane from natural gas is catalytically converted or reformed into hydrogen gas which then forms the hydrogen enhanced methane/hydrogen gas blend. The reactions which obtain this conversion include:



In an another important aspect, prior to the conversion reaction, hydrogen

sulfide and other acid components such as COS, RSH and RSSR are removed from the natural gas using a physical solvent to provide a sweet natural gas. A physical solvent selectively removes hydrogen sulfide and other acid gases, but minimizes the removal of carbon dioxide and other inert gases such as helium, argon, and nitrogen. In this aspect, the physical solvent is selected from the group consisting of methanol, a blend of dimethyl ethers of polyethylene glycol (molecular weight about 280), propylene carbonate (b.p.. of 240°C, N-methyl-2-pyrrolidone (b.p. 202°C), a blend of oligoethylene glycol methyl isopropyl ethers (b.p. about 320°C), tri-n-butyl phosphonate (b.p. 180°C at 30 mm Hg) and methyl cyano-acetate (b.p. 202°C). The sweet natural gas is mixed with sufficient water to permit sufficient production of hydrogen from the methane to achieve flame stability or a BTU/Scf value of at least about 110. In this aspect, it is important that the hydrogen sulfide and other acid gases are removed prior to reforming a portion of the methane to hydrogen because the reformation is a catalyzed reaction where the catalyst may be poisoned by the hydrogen sulfide gas and other acid gases. Catalysts which are sensitive to the acid conditions and which may be used in this aspect of the invention include the C11 Series catalyst from United Catalyst Inc., R67 from Haldor Topsoe and G1-25 from BASF. High temperature "shift catalysts" for sweet natural gas generally are iron, chrome and copper. Low temperature "shift catalysts" for sweet natural gas generally are made from copper, zinc and aluminum.

In another important aspect, the reformation reaction is done under acid or sour conditions using catalysts such as a C25 Series catalyst from United Catalyst Inc., K8-11 catalyst from BASF and SSK catalyst from Haldor Topsoe. In general these catalysts are chrome molybdenum catalysts. In this aspect of the invention, the sour natural gas and water are mixed with the water being in amount which will result in a methane gas/water blend which will permit the formation or reformation of sufficient hydrogen gas to provide flame stability for the hydrogen rich methane/hydrogen gas blend which does not have in excess of 40 volume percent methane.

In another aspect, the natural gas reserves may have as low as 35, 25 or even less than 20 volume percent methane and still provide more power than

pipeline quality methane. In practicing the invention, sufficient methane should be converted into hydrogen to produce a methane/hydrogen gas blend with at least 6 volume percent, and preferably from about 6 to about 10 volume percent hydrogen. This will produce a hydrogen enhanced methane/hydrogen gas blend with stable flammability that is very effective for fueling gas turbines for the generation of electric power.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a flow plan illustrating the process of the invention.

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DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1 natural gas having a methane concentration of not more than about 40 volume percent is moved from the well and treated with a physical solvent such as methanol, a blend of dimethyl ethers of polyethylene glycol, propylene carbonate, N-methyl-2-pyrrolidone, a blend of oligoethylene glycol methyl isopropyl ethers, tri-n-butyl phosphonate, and methyl cyano-acetate to remove hydrogen sulfide gas and other acid gas components without removing inert gases to provide a sweet natural gas with not more than about 40 volume percent methane. The sweet natural gas then is conveyed via line 1 to a zinc oxide guard bed 2 to prevent the emissions of hydrogen sulfide gas. The sweet natural gas is conveyed from the zinc oxide bed and mixed with water in line 3 to provide a methane gas/water blend. The gas/water blend is conveyed at about 70°F and at about 355 psig in line 3 to a feed effluent heat exchanger 4 where the temperature of the sweet natural gas/water blend is raised to about 800°F. Sufficient water to be mixed with the natural gas to permit sufficient conversion to hydrogen to provide flame stability to a hydrogen enhanced dehydrated methane/hydrogen gas blend when it is delivered to the gas turbine generator for the generation of power. After the sweet natural gas is mixed with water and heated in the feed effluent exchanger, the heated sweet natural gas/water blend is conveyed via line 5 at about 345 psig and about 800°F to a heat recovery steam generator coil (HRSG coil) to further raise the temperature of the sweet natural gas/water blend and

provide a hot sweet gas/water blend having a temperature of about 950°F in line 3. The hot sweet gas/water blend then is conveyed via line 7 to a reforming reaction chamber 8 at about 340 psig for converting a part of the methane in the sweet gas/water blend to a hydrogen enhanced methane/hydrogen gas/water blend. The methane in the sweet gas/water blend undergoes a catalyzed reaction to react the methane and water to produce hydrogen gas at least about 700°F and preferably from about 900 to about 950°F and about 340 psig. Higher temperatures facilitate the conversion, while higher pressures adversely affect the conversion. Pressure should not exceed 1500 psig. After conversion of sufficient methane to hydrogen to provide at least about 6 volume percent hydrogen in the gas present after dehydration (hereinafter described), the hydrogen enhanced methane/hydrogen gas/water blend is conveyed back to the feed effluent exchanger via line 9 at about 855°F and 335 psig to transfer heat to the water and methane gas entering the feed effluent exchanger. After the temperature of the hydrogen enhanced methane/hydrogen gas/water blend is reduced, it is conveyed via line 10 to a dehydrating knockout drum (KO drum) 12 to reduce the water content of the hydrogen enhanced methane/hydrogen gas blend. The dew point is lowered in the KO drum to permit water to condense and separate from the gas. Sufficient water is removed to permit flame stability and provide the gas with at least about 110 BTUs per standard cubic foot of gas. In general, from about 97 to about 99 or more weight percent of the water is removed from the gas. The water resulting from dehydrating the hydrogen enhanced methane/hydrogen gas/water blend is removed from the KO drum 12 via line 14 using condensate pump 16 and is conveyed back to the feed effluent exchanger 4 via line 18 at about 100°F at about 500 psig. The dehydrated hydrogen enhanced methane/ hydrogen gas blend which now has at least 6 volume percent hydrogen or sufficient hydrogen gas to provide flame stability is fed from the KO drum to a gas turbine generator via line 20 at about 100°F at about 325 psig. There the gas has at least about 110 BTUs per standard cubic foot of gas and provides a stable flame for the gas turbine generator.

The same process may be used in utilizing a sour natural gas using a catalyst which will not be sensitive or poisoned by the acid gases in the natural gas. To keep the process compatible with the environment, however, at least some of the acid gases such as H_2S may be removed at least in part.

5 In another embodiment not shown in the drawings, the power generated by the dehydrated hydrogen enhanced methane/hydrogen gas blend may be augmented by the injection of inert gases to increase the mass flowing through the gas turbine generator. In this aspect, the total amount of gas supplied as fuel still must have flame stability and have at least about 110 BTUs/Scf. In general, the
10 inert gases are injected after the hydrogen enhanced methane gas blend is combusted in the turbine, but before the hot gas enters the expander of the turbine. Depending upon the amount of hydrogen gas that is in the methane gas blend, the output of the turbine may be raised by about 0.5 to about 9%. The power increase is about equal to the percentage of mass flow increase through the expander of the
15 turbine.

The invention is illustrated by the following example.

EXAMPLE I

GAS TURBINE PERFORMANCE			
Site Conditions	Units	No Ang	Power Ang
Ambient Temperature	°F	60	60
Ambient Pressure	psia	11.57	11.57
Ambient Relative Humidity	%	60	60
Inlet Pressure Drop	In H ₂ O	3.0	3.0
Performance			
Gross Generator Output	kW	156,100	157,100
Heat Consumption (LHV)	Btu/h x 10 ⁻³	1,477.1	1,486.9
Heat Rate (LHV)	Btu/kWh	9,461	9,462
Fuel 1 Conditions			
Composition	% Vol		
Carbon Dioxide		62.5	62.5
Hydrogen		10.0	10.0
Nitrogen		5.4	5.4
Methane		20.3	20.3
Misc.		1.8	1.8
LHV	Btu/Lb	2,424.0	2,424.0
	Btu/Scf	212.5	212.5
Fuel Gas Flowrate	lb/s	169.3	170.4
Pressure	psia	325	325
Temperature	°F	80	80

Power Aug Inj. Conditions			
Composition	% Vol		
Carbon Dioxide		100.0	100.0
Flowrate	lb/s	0.0	4.0
Pressure	psia	285	285
Temperature	°F	300	300
Exhaust Gas Conditions	Units	No Aug	Power Aug
Exhaust Gas Flow	lb/s	925.3	930.4
Exhaust Gas Temperature	°F	1,093.1	1,095.1
Exhaust Gas Composition	% Vol		
Carbon Dioxide		13.79	14.12
Argon		1.07	1.07
Nitrogen		65.78	65.53
Oxygen		9.83	9.74
Water		9.53	9.55
Exhaust Pressure Drop	In H₂O	15.0	15.0
Nox (Thermal)	Ppmvd @ 15% O₂	<10	<10

WHAT IS CLAIMED IS:

1. A method for fueling a gas turbine with methane from natural gas reserves having relatively low concentrations of methane, the method comprising:
5 mixing natural gas and hydrogen gas, the natural gas having not more than about 40 volume percent methane gas to provide a hydrogen enhanced methane gas blend, the hydrogen gas being in an amount effective for providing flame stability for the hydrogen enhanced methane gas blend; and
fueling a gas turbine with the hydrogen enhanced methane gas blend.
10
2. The method for fueling a gas turbine as recited in claim 1 wherein the hydrogen enhanced methane gas blend comprises at least about 6 volume percent hydrogen gas.
- 15 3. The method for fueling a gas turbine as recited in claim 1 wherein the method further includes dehydrating the natural gas or hydrogen enhanced methane gas blend, the dehydration effective for providing the hydrogen enhanced methane gas blend with at least about 110 BTUs per standard cubic foot of gas.
- 20 4. The method for fueling gas turbine as recited in claims 1 or 3 wherein the natural gas has less than about 35 volume percent methane and the hydrogen enhanced methane gas blend has from about 6 to about 10 volume percent hydrogen gas.
- 25 5. The method for fueling a gas turbine as recited in claims 1 or 3 wherein the natural gas has less than 20 volume percent methane and the hydrogen enhanced methane gas blend has from about 6 to about 10 weight percent hydrogen gas.
- 30 6. A method for fueling a gas turbine with methane from natural gas reserves having relatively low concentrations of methane, the method comprising:

removing at least one acid component from natural gas having not more than about 40 volume percent methane gas to provide a sweet natural gas;

mixing the sweet natural gas and water to provide a hydrated sweet natural gas, the water in the hydrated sweet natural gas being in amount effective for
5 permitting the conversion of a portion of the methane in the sweet natural gas to hydrogen gas and effective for providing a flame stable dehydrated hydrogen enhanced natural gas;

catalytically converting a portion of the methane to hydrogen gas in the hydrated sweet natural gas to provide a hydrated hydrogen enhanced natural gas,
10 the conversion effective for providing the flame stable dehydrated hydrogen enhanced natural gas;

dehydrating hydrated hydrogen enhanced natural gas to provide the flame stable dehydrated hydrogen enhanced natural gas; and

fueling a gas turbine with the dehydrated hydrogen enhanced natural gas.
15

7. The method for fueling a gas turbine as recited in claim 6 wherein removing the acid component from the natural gas includes removing hydrogen sulfide from the natural gas.

20 8. The method for fueling a gas turbine as recited in claim 6 wherein the hydrated hydrogen enhanced natural gas is dehydrated in an amount effective for providing the dehydrated hydrogen enhanced natural gas with at least about 110 BTUs per standard cubic foot of gas.

25 9. The method for fueling a gas turbine as recited in claim 7 wherein the hydrogen sulfide is removed from the natural gas with a physical solvent while minimizing removal of any inert gas.

30 10. The method for fueling a gas turbine as recited in claim 9 wherein the physical solvent is selected from the group consisting of methanol, a blend of

dimethyl ethers of polyethylene glycol, propylene carbonate, N-methyl-2-pyrrolidone, a blend of oligoethylene glycol methyl isopropyl ethers, tri-n-butyl phosphonate, methyl cyano-acetate and mixtures thereof.

5 11. The method for fueling a gas turbine as recited in claims 6 through 10 wherein the dehydrated hydrogen rich natural gas comprises at least 6 volume percent hydrogen gas.

10 12. The method for fueling a gas turbine as recited in claims 6 through 10 wherein the methane in the hydrated sweet natural gas is catalytically converted using a shift catalyst selected from the group consisting of iron/chrome/copper, copper/zinc/aluminum and mixtures thereof.

15 13. The method as recited in claims 6 or 8 wherein the natural gas does not have more than about 35 volume percent methane and the dehydrated hydrogen enhanced natural gas comprises from about 6 to about 10 volume percent hydrogen gas.

20 14. The method as recited in claims 6 or 8 wherein the natural gas does not have more than about 20 volume percent methane gas and the dehydrated hydrogen enhanced natural gas comprises from about 6 to about 10 volume percent hydrogen gas.

25 15. A method for fueling a gas turbine with methane from natural gas reserves having relatively low concentrations of methane, the method comprising:
 mixing the sour natural gas and water to provide a hydrated sour natural gas, the water in the hydrated sour natural gas being in amount effective for permitting the conversion of a portion of the methane in the sour natural gas to hydrogen gas and effective for providing a flame stable dehydrated hydrogen
30 enhanced natural gas, the sour natural gas having not more than about 40 volume

percent methane;

catalytically converting a portion of the methane to hydrogen in the hydrated sour natural gas to provide a hydrated hydrogen enhanced natural gas, the conversion effective for providing the flame stable dehydrated hydrogen

5 enhanced natural gas;

dehydrating hydrated hydrogen enhanced natural gas to provide the flame stable dehydrated hydrogen enhanced natural gas; and

fueling a gas turbine with the dehydrated hydrogen enhanced natural gas.

10 16. The method for fueling a gas turbine as recited in claim 15 wherein the hydrated hydrogen enhanced natural gas is dehydrated in an amount effective for providing the dehydrated hydrogen enhanced natural gas with at least about 110 BTUs per standard cubic foot of gas.

15 17. The method for fueling a gas turbine as recited in claim 15 wherein the hydrated hydrogen enhanced natural gas comprises at least 6 volume percent hydrogen gas.

18. The method for fueling a gas turbine as recited in claim 15 wherein
20 the methane in the hydrated sour natural gas is catalytically converted using a chrome/molybdenum catalyst.

19. The method as recited in claims 15 or 16 wherein the natural gas does not have more than about 35 volume percent methane gas and the dehydrated
25 hydrogen enhanced natural gas comprises from about 6 to about 10 volume percent hydrogen gas.

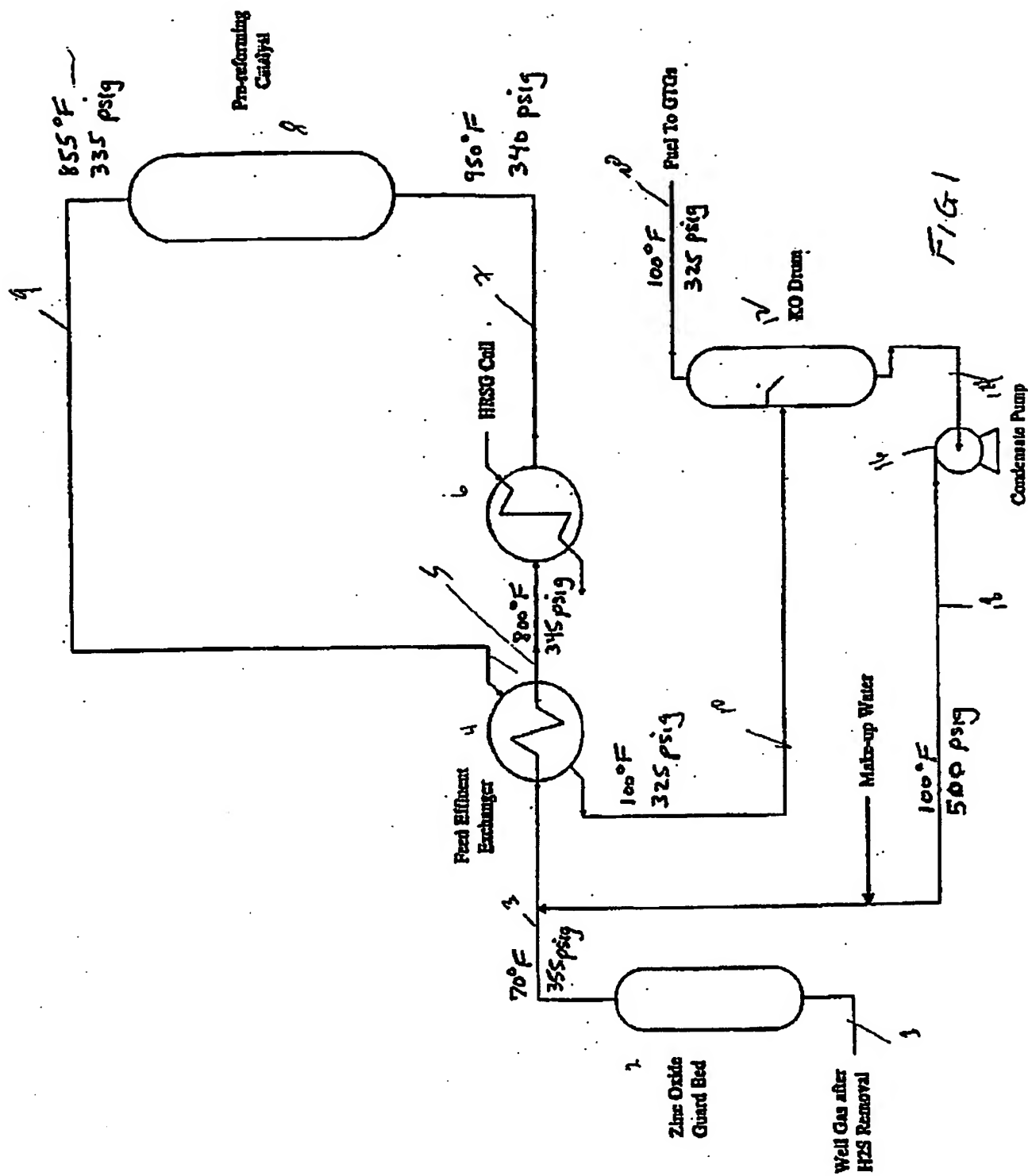
20. The method as recited in claims 15 or 16 wherein the natural gas does not have more than about 20 volume percent methane gas and the dehydrated
30 hydrogen enriched natural gas comprises from about 6 to about 10 volume percent

hydrogen gas.

21. The method as recited in claim 6 where the method further includes
injecting into the turbine an inert gas with the dehydrated hydrogen enhanced
5 natural gas.

22. The method as recited in claim 15 wherein the method further
includes injecting into the turbine an inert gas with the dehydrated hydrogen
enhanced natural gas.

10



INTERNATIONAL SEARCH REPORT

Int. Application No

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A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F02C3/20 F02C3/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 351 094 A (ICI PLC) 17 January 1990 (1990-01-17) page 11; figures	1-5
A	US 4 132 065 A (MCGANN RODNEY) 2 January 1979 (1979-01-02) the whole document	1-22
A	US 3 868 817 A (MARION CHARLES P ET AL) 4 March 1975 (1975-03-04) the whole document	1-22
A	GB 2 085 314 A (ICI PLC) 28 April 1982 (1982-04-28) the whole document	1-22
	-/-	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Int. Application No.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>EP 0 723 068 A (TOPSOE HALDOR AS) 24 July 1996 (1996-07-24) abstract; figures</p>	1-22

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Information on patent family members

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